

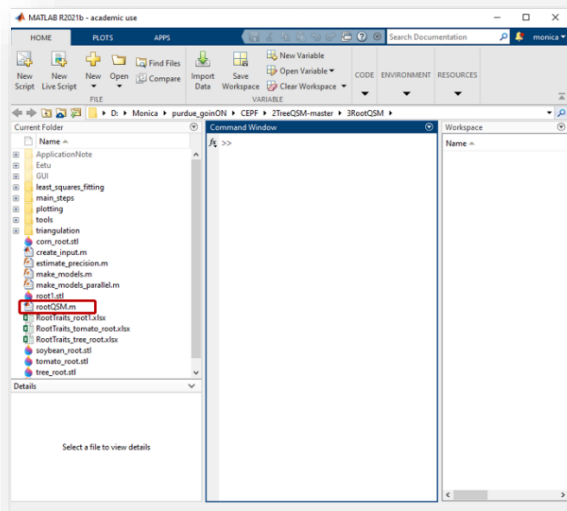
# 4DROOT SOFTWARE

## INSTALL FROM MATLAB:

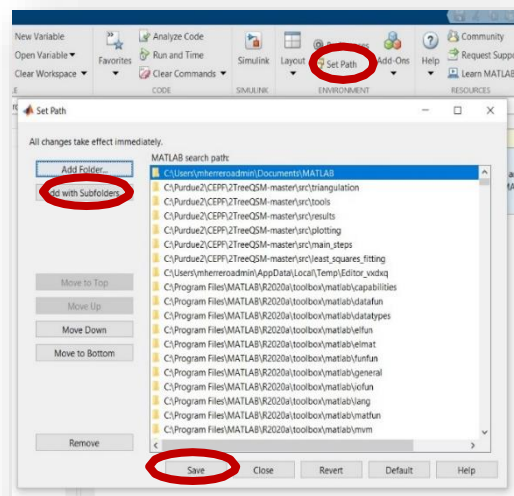
- COMPUTER VISION TOOLBOX
- PARTIAL DIFFERENTIAL EQUATION
- STATISTICS AND MACHINE LEARNING TOOLBOX

## INSTRUCTIONS: CODE FOR MODELING THE ROOTS

1. Download 4DRoot
2. Start MATLAB 2017 or newer and set the main path to the root folder, where rootQSM.m is located (from 4DRoot).

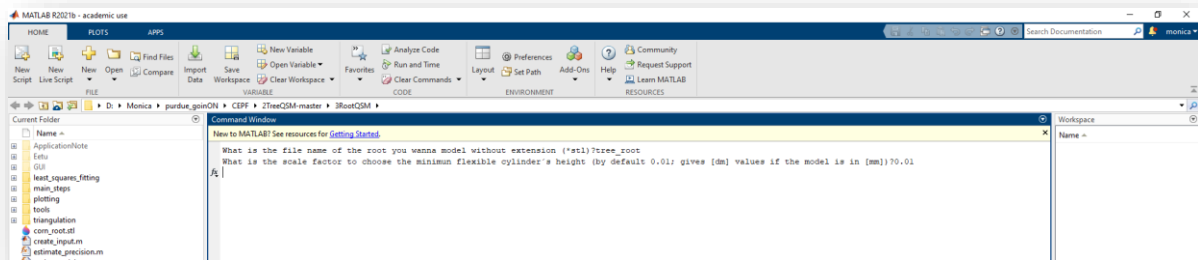


3. Use Set Path -> Add with Subfolders -> Open -> Save -> Close to add the subfolders, where all the code of the software is is, to the paths of MATLAB.

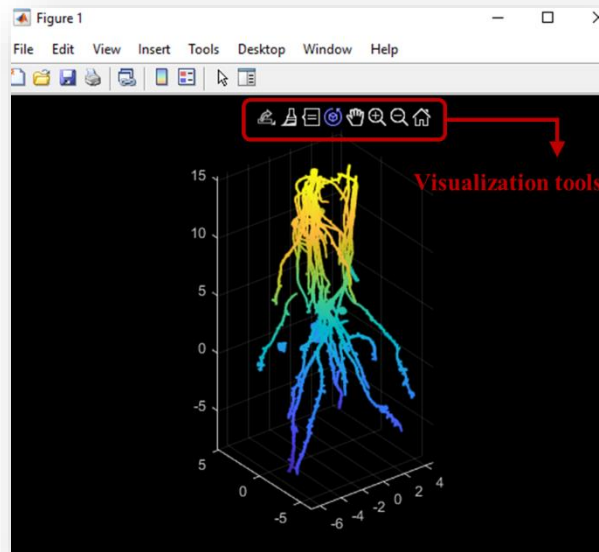


#### 4. Run rootQSM.m:

4.1. Inputs: 3D scan of the root in \*.stl format, scale factor to reconstruct the cylindrical fitting and desire to view the 3Dscan.

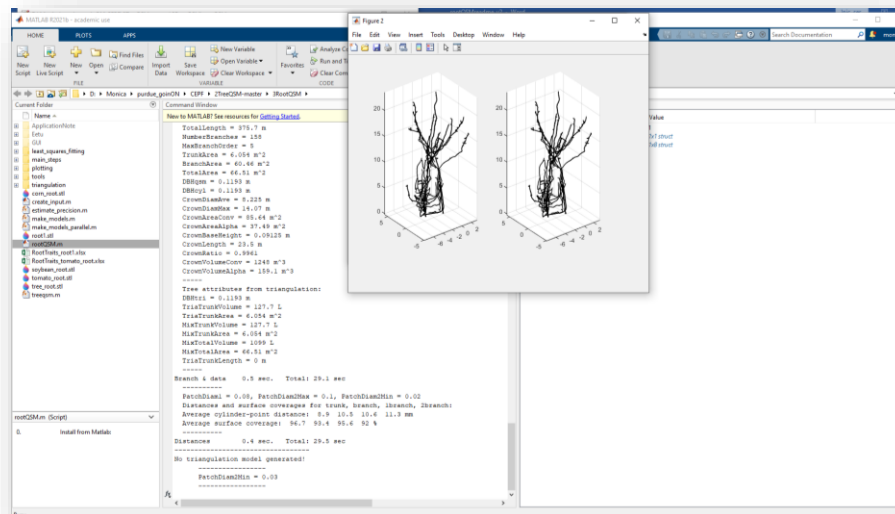


4.2. Visualization of the 3D scan as an option. Visualization tools are included.



After the visualization, the process is paused. To continue, press any key.

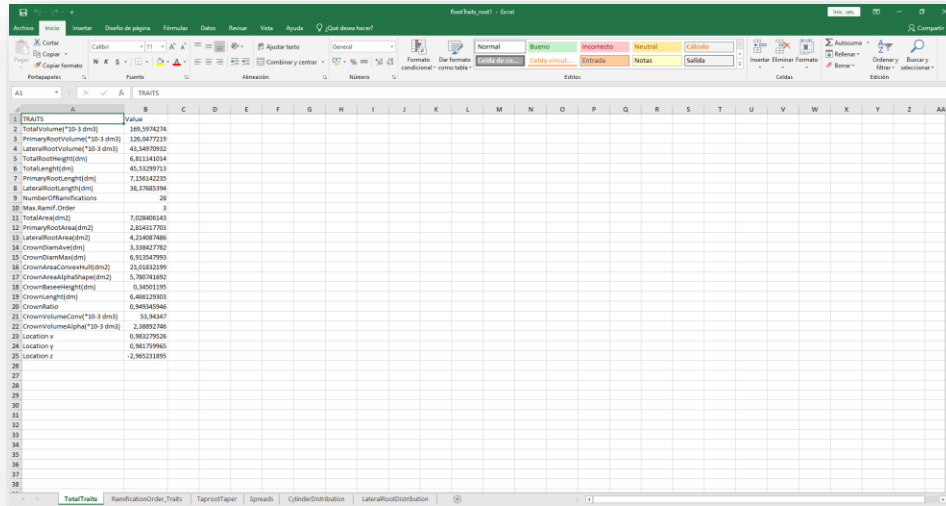
4.3. Numerical and graphic results of each approximation of the cylindrical model (upside down) when 3D Root is running.



4.4. Output: Phenotypic root traits and their distribution are extracted to an excel file with several sheets.

The units of the traits are:

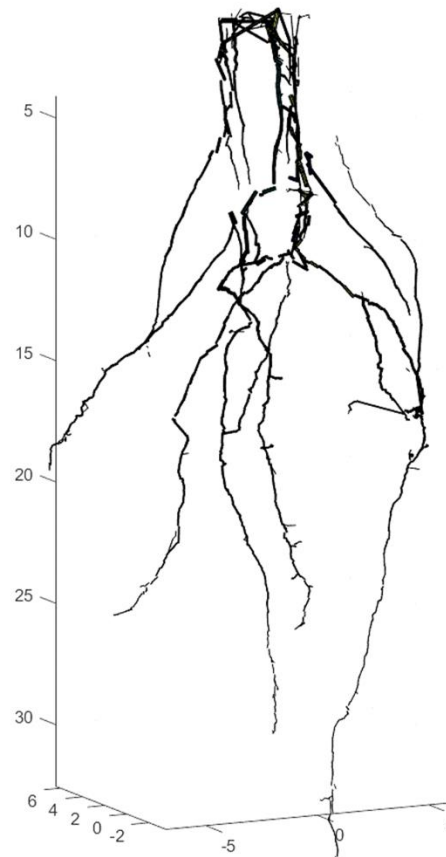
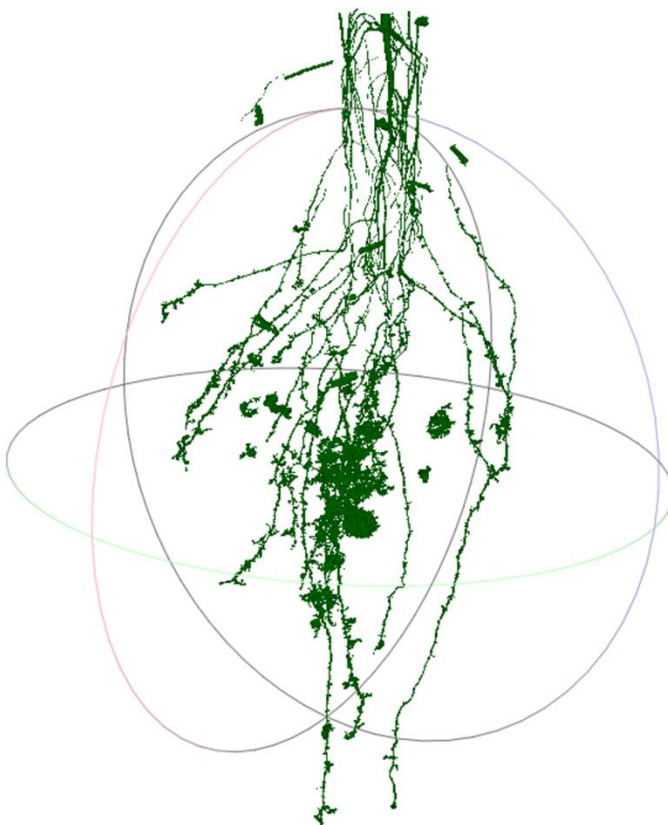
- [L] as length and height: [ud] from the scan / scale factor
- [L<sup>2</sup>] as area: [ud<sup>2</sup>] from the scan / scale factor
- [L<sup>3</sup>] as volume: [ud<sup>3</sup>] from the scan / scale factor \* 10<sup>-3</sup>



The screenshot shows an Excel spreadsheet with a single sheet named 'TRAITS'. The data is organized into two columns: 'TRAITS' and 'Value'. The 'TRAITS' column lists 25 different root traits, and the 'Value' column contains their corresponding numerical values. The traits include volume, length, area, and location metrics.

TRAITS	Value
1. TotalVolume ("3D-3 dm3")	189.5974276
2. PrimaryRootVolume ("3D-3 dm3")	126.8477228
3. LateralRootVolume ("3D-3 dm3")	43.34970932
4. TotalRootLength (dm)	6.81144314
5. TotalRootArea (dm2)	45.5209713
6. PrimaryRootLength (dm)	7.156142235
7. LateralRootLength (dm)	38.17683264
8. NumberOfRamifications	28
9. Max Ramif. Order	3
10. TotalArea (dm2)	7.028408141
11. PrimaryRootArea (dm2)	2.814117703
12. LateralRootArea (dm2)	4.214290438
13. CrownDiamMax (dm)	3.338427782
14. CrownDiamMin (dm)	6.912547993
15. CrownAreaCone (dm2)	21.61832399
16. CrownAreaAlphaShape (dm2)	5.786741692
17. CrownBisectHeight (dm)	0.30251135
18. CrownLength (dm)	6.466223933
19. CrownRatio	0.949349546
20. CrownVolumeAlpha ("3D-3 dm3")	10.343487
21. CrownVolumeCone ("3D-3 dm3")	2.38892748
22. Location x	0.983279526
23. Location y	0.361729965
24. Location z	-2.965211895

**\*Noise removal:** noise from the segmentation between soil and root can be removed by 4DRoot by choosing an appropriated *scale factor* (left: 3D scan from a root, right: QSM from the root).



CITE:

1. Raunonen P, Kaasalainen M, Åkerblom M, Kaasalainen S, Kaartinen H, Vastaranta M, et al. Fast automatic precision tree models from terrestrial laser scanner data. *Remote Sens.* 2013;5(2):491–520.
2. Herrero-Huerta, M., Meline, V., Iyer-Pascuzzi, A. S., Souza, A. M., Tuinstra, M. R., & Yang, Y. (2021). 4D Structural root architecture modeling from digital twins by X-Ray Computed Tomography. *Plant Methods*, 17(1), 1-12.